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Utensils for the Electric Range

by

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UTENSILS FOR THE ELECTRIC RANGE

By Evelyn H. Roberts

The use of electric equipment is extensive in the homes of the Northwest, largely because of the availability of hydro-electric power and consequent low household rates. Electric manufacturers and distributors have found a ready market for their products in this area. Numerous models and variations of each type of equipment are offered to the puzzled housewife who has relatively little information upon which to base her selection. Several experimental projects planned to supplement the housewife's information along this line have been carried on in the Division of Home Economics of the Washington Agricultural Experiment Station. One bulletin entitled "Baking Vegetables Electrically" dealt with oven usage and practice. This work led to the present study of utensils suitable for use on the electric range. The purpose of this investigation was to determine by means of standardized tests which pans were the most efficient for use in top stove and oven cookery.

EQUIPMENT AND METHOD

The top of an electric range is supplied with various surface units on which utensils are placed for cooking. All such units are not alike and so an attempt was made to secure as many different types as possible for test. Over 75 per cent of the electric range manufacturers supply the open unit. The remainder furnish the solid unit, the rod unit, the cone unit, or modifications of these.

Units. Each unit has its distinguishing characteristics. In the open unit, the heating wires are mounted in grooves in a flat porcelain block. In the solid unit, the wires are embedded in a cast iron plate, being insulated from the plate by some powdered material. A modification of the solid unit is not as heavily built, the wires being mounted between two sheets of iron or steel. In the rod unit, the wire is embedded in curved metal tubes or rods. A modification of the rod unit has a covering of sheet metal over the rods. The top surface is flat except where the rods rise somewhat above the surface. The cone unit has its heating wires mounted in grooves in a porcelain block shaped like a cone, and the heat is deflected upward by a chromium-plated conical reflector. These units are illustrated in Fig. 1.

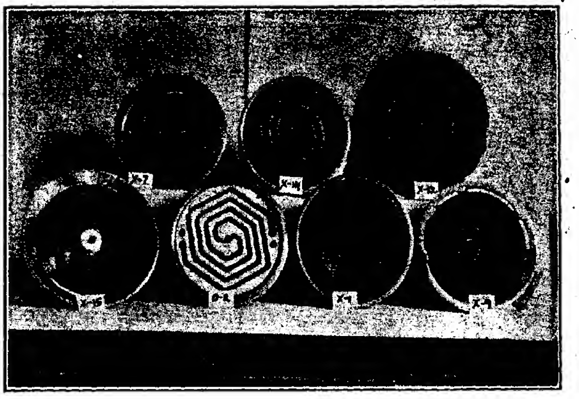

Figure 1. Various units used in tests: rod, ring, cone, open, and solid types.

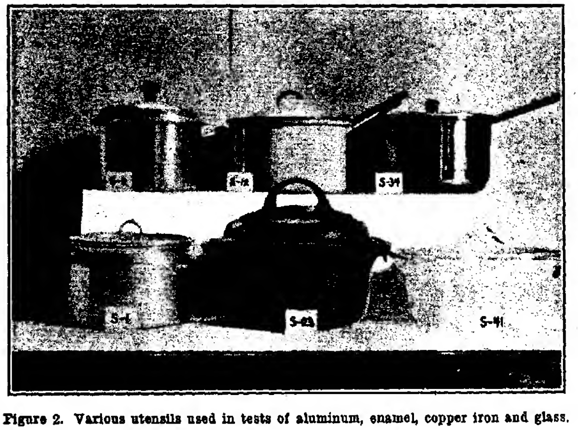

Figure 2. Various utensils used in tests of aluminum, enamel, copper iron and glass.

The purpose of any surface unit is to afford ready access of the heat from the wires to the utensil. The most desirable condition exists when the utensil is in direct contact with the unit. This is based on the fact that heat is quickly transferred from one metal to another when the metals touch, but more slowly the farther they are separated by air. Material in a pan is heated rapidly by conduction through a solid material and less rapidly by air currents. Conducted heat may be illustrated by the heating of the metal handle on a frying pan during the cooking process. Convected heat is that which heats a room, air currents carrying the warm air above a register or radiator to other portions of a room. A third type of heat transference is radiant heat. This is radiated out from a hot body and is absorbed by cold bodies in the path of the radiations. During any cooking process on top of a stove, utensils are heated mostly by conducted and convected heat, but somewhat by radiant heat. Oven cooking, on the other hand, is done largely by radiant heat and partially by convected heat, but very little by conducted heat.

The surface unit of an electric stove must be designed to bring the heat from the wires to the utensil as easily and as quickly as possible. The heat from the wires travels downward and sideward as well as upward so that the unit itself becomes heated. A heavily built unit is likely to be slow in heating and a lightly built unit is quick in heating. Once the unit is heated and the contents of the utensil are brought to boiling, the current may be shut off. Then the heavily built unit will hold the heat much longer, maintaining boiling in the utensil in some cases over 20 minutes. The lightly built unit also retains some heat and maintains boiling temperatures within the utensil for 8 to 10 minutes. These periods can readily be used in cooking and this is a particular feature in the use of an electric stove. Certain utensil characteristics may change the length of these periods of cooking on "stored" heat. This point will be discussed later.

Utensils. The utensils available for test were of many shapes and sizes. For uniformity, two- or three-quart utensils were selected for most of the tests, mainly because they fitted the small diameter units on most electric stoves. A few tests were made with four-, five-, and six-quart utensils on the large diameter units. Saucepans with flat bottoms and straight sides, others with small bottoms and flaring or convex sides, shallow and tall pans, rough and shiny pans, and pans of various metals and materials were employed in the tests. Altogether eight aluminum, ten enamelware, two stainless steel, one iron dutch oven, four copper saucepans, and one glass casserole were used in the top stove tests on 30 small and large units.

Method of test. The method used was a simple boiling test, each detail of which was standardized as much as possible. Water at exactly

68° F. was weighed into the utensil, 1000 or 1500 grams in most cases (approximately one or one and one-half quarts respectively), and the pan was placed on the cold unit. A thermocouple connected to a pyrometer was inserted through a hole in the lid of the utensil in order to measure the temperature of the water within the pan. The current was turned on until the water reached boiling, and a stop watch was used to measure the time necessary to bring the water just to boiling and also the time it remained at boiling because of the retained heat in the unit. The pan and its contents were reweighed at the end of this period. A special watthour meter was used to measure the electric input in decimal parts of a kilowatt hour. Room temperatures were maintained between 64 and 72° F. From these measurements the thermal efficiency of the utensil on the unit was computed. The formula reads as follows: the thermal efficiency equals the heat in calories absorbed by the metal of the utensil, plus the heat absorbed by the water in the pan, plus the heat lost by evaporation, divided by the heat in calories supplied by the electricity times 100. Fifty-five per cent efficiency means that 55 per cent of the heat supplied by the electricity is used in heating the pan and water and in evaporation of some water, and 45 per cent of such heat is lost in heating the unit or lost into the air of the room. The higher this thermal efficiency is, the more excellently designed is the range unit and the better the utensil.

Electrical and heating engineers have been working for years to design efficient heating devices. If the top of a coal range is completely filled with pots and pans, about 18 per cent of the heat supplied is utilized. Kerosene and gasoline stoves are approximately 25 per cent efficient. Gas stoves are approximately 35 per cent efficient, and electric stove units are generally reported to be between 40 and 45 per cent efficient. If an electric current is applied as directly as possible to the article to be heated, as in immersion heaters, approximately 90 per cent efficiency is attained.

In the tests to be described, efficiencies higher than 45 per cent are mentioned in electric stove tests. The values are higher because the formula used included the heat utilized in evaporation of some water, which most of the previous investigators have disregarded.

EXPERIMENTAL WORK ON UNITS

Detailed records of the experiments are held in a bound typewritten report in the Library at the State College of Washington under the title, "The Thermal Efficiency of Utensils for Use with the Electric Range," and may be borrowed by interested readers. For brevity, only the general and a few specific conclusions are here recorded.

Each set of experiments was made to study some variable factor in the relationship of utensil to unit with a standardized method. These variable factors were: the wattage, and type and diameter of the unit; the material of the pan; the color and polish of the utensil; the bottom, sides and cover, thickness of wall, height of wall, and volume of water. Each factor had to be varied separately and the results are stated separately.

Wattage and Diameter of Unit. In buying an electric stove, the housewife is often at a loss to know what wattage unit to buy. If her family consists of four or five members, she can effectively use a two- or three-quart saucepan for many cooking operations. Should she then obtain a 750, 1000, 1250, or 1800 watt unit, or what combination of these? Will higher wattage units save her time and electricity, or not? These are questions of the characteristics of the unit, rather than of the utensil, but since no test could be made without both, an attempt was made with several aluminum pans to find the answers. One electric range is supplied with four open units of the following wattages: 750, 1000, 1250, and 1500. The first two are six inches and the last two are eight inches in diameter.

Tests were made to find the time to boil and the thermal efficiency when two small aluminum pans were used on these four units. These pans had approximately the same dimensions and contained the same amount of water. One had a shiny bottom and the other a black lacquered bottom. Further variation was possible by turning the switch of the 1000 watt unit to "low" or 250 watts, and "medium" or 500 watts. The 1500 watt large-sized unit could likewise be adjusted to "medium" or 750 watts. Data are shown in Table 1.

Table 1. The Effect of Wattage Variation on Time to Boil and Thermal Efficiency of Aluminum Pans on Open Units

Watts	Aluminum pan No. 1			Aluminum pan No. 2		
	Time to boil (min.)	Input (Kwhr.)	Efficiency (per cent)	Time to boil (min.)	Input (Kwhr.)	Efficiency (per cent)
Small units						
250	42	.19	55.5	—	—	—
500	22	.20	57.6	21	.19	63.4
750	16	.22	55.9	14	.19	65.1
1000	12	.22	58.7	11	.20	65.3
Large units						
750	18	.27	46.8	18	.27	47.2
1250	12	.29	47.3	12	.28	48.2
1500	11	.30	48.6	10	.29	49.9

Comparing the first two columns of the table, it is noted that as the wattages increase the time to boil decreases. From the first and third columns it is noted that though the wattages vary the actual electric inputs are relatively the same. The input for the 1000-watt unit was the greatest of the first four, .22 Kwhr., and that for the 1500 watt unit the greatest for the large diameter units, .30 Kwhr. In other words when the unit is used at its maximum wattage, the water boils the quickest, the greatest input is needed, and the thermal efficiency is the highest. Next, comparing the first and fourth columns, the efficiencies for the first four wattage ratings are relatively the same, averaging 56.9$\pm$ 1.2 per cent. The same applies to the last three efficiencies which average 47.6 $\pm$ 0.5 per cent. Efficiencies in the seventh column have the same characteristics, those for the small pans on the large units running 9 to 16 per cent less than on the small units.

The 750-watt small unit and the 750-watt large unit differ physically in that the larger unit has a greater mass to be heated. The use of the small unit involves a shorter boiling time, less electrical input, and nine per cent higher efficiency for pan No. 1. The water in pan No. 2 also boiled more quickly on the small unit, and the test required considerably less input and showed 18 per cent greater efficiency for the small unit than for the large. Next, comparing the 1000-watt small unit with the large 1250-watt unit, it is found that the times to boil are approximately the same for both pans, the latter unit requiring greater electrical input and having a lower efficiency.

The general conclusions from the wattage variation experiments are that small units operate at approximately 40 per cent less electric cost than the large units when small pans are used and that the maximum wattage for each size of unit is the most efficient. A little time may be saved by using the large units but only at a greater electric cost.

Type of Unit. The preceding test was made on open units, but since there are a number of different kinds of units, it is logical to ask which has the best characteristics. The second series of experiments was made with all types of pans of the two-quart size on the seven types of small units available. Housewives were also asked for their comments on these units. Results are summarized in Table 2 as to speed of heating, heat retention, electric input, thermal efficiency, durability, and cost of replacement.

Further laboratory tests showed that the flatness of the top of the surface unit influences the speed and efficiency of the heating process. The utensil should also be flat as to bottom, and the two surfaces should be in contact at many if not all points for maximum efficiency. Separation by an air space, 1.0 millimeter thick, increased the time to reach boiling from 15 to 19 minutes and decreased the

efficiency from 71.5 to 59.9 per cent in tests with an aluminum pan on a ring unit.

Table 2. Characteristics of Various Surface Units

Type	Speed in heating	Heat retention	Electric input	Thermal efficiency	Durability	Replacement cost
Open	slow	good	average	good	fair	low
Solid	slow	excellent	high	good	excellent	high
Ring I	fast	average	low	excellent	good	average
Ring II	average	good	high	good	good	high
Rod I	very fast	average	average	excellent	good	average
Rod II	fast	average	average	good	good	average
Cone	average	poor	high	fair	fair	low

EXPERIMENTAL WORK ON TOP-STOVE UTENSILS

With a limited amount of money to spend for a utensil to be used on top of the electric range, the housewife will first decide upon the capacity of the utensil she wants. From then on she has little to guide her in the choice of metal, shape, and finish. She may know but little of the chemical properties of the metal pans and may even have a few qualms as to using certain ones. The physical characteristics and cost are the only perceptible features. Enough experimental work has been carried on, however, to give her information upon which to base her selection. The following pages contain a discussion of the effect of material, color, and polish; the effect of the type of bottom, sides, and top; the wall thickness; the size and shape of pan; and the volume of water with relation to the speed and efficiency of the boiling process. These may then be translated into selection factors for utensils.

Effect of Material. The question of the metal of which a utensil is made is worthy of consideration. Both American and German medical associations report that there is no physiological hazard in the use of cooking utensils of metal. Considerations of cost, suitability, design, ease of cleaning, and weight enter the mind of the shopper when she is selecting utensils. Whether to purchase iron, stainless steel, aluminum, enamel ware, copper, or some other kind of ware for surface cooking or for oven cooking is a real and pertinent question.

It is rather hard to come to a definite conclusion on this point. No one metal or material stands out as having more desirable characteristics than the others. However, if units and utensils are considered together, some combinations show up better than others. From the series of experiments on iron, steel, copper, aluminum,

enamel, and glass ware the following recommendations are made as to their use with the various units:

Open units, any metal pan with flat dark bottom is good.

Solid units, iron and aluminum pans are good.

Ring units, iron and aluminum pans are good.

Rod units, enamel and aluminum pans with black bottoms are good.

Cone unit, copper pan with black bottom and glass ware are good. The pans of the various materials, which had the best characteristics in design and finish, are illustrated in Figure 2.

The Color and Polish of the Utensil. There is also the question of the color of the utensil and its possible effect on speed of boiling and thermal efficiency. Because of the interest in decorating kitchens in bright colors, manufacturers are offering gaily colored utensils. A white and green enameled sauce-pan is more attractive than a black cast iron dutch oven. Only a few tests were made on this color problem. Results for one gray and one white enamel pot of the same capacity showed that the water in the gray pot boiled a little sooner and that the gray pot was slightly more efficient than the white pot on all units. The black iron pot had an average efficiency of approximately 63 per cent for all units while the gray and white enamel ware averaged nearer 56 per cent efficiency.

The polish may affect the heat absorptive power of a surface as well as the color. The cast iron pot mentioned above had a rough black surface. One stainless steel pot had a dull finish; another, a very shiny outer surface. Of these three, the water in the iron pot was not always faster in reaching boiling, but the pot was generally more efficient on all units than the shiny steel utensil. The dull-surfaced stainless steel pot had about the same average efficiency as the cast iron pot. A further fact about these three pans is that the cast iron pot weighed approximately 50 per cent more than the dull steel pan, and almost three times the weight of the shiny steel pan. Hence the polish of the surface seems to have more effect on the speed of boiling and the efficiency than the weight of metal to be heated.

As mentioned before, objects are heated in part by heat which radiates from some source. If the object, as a utensil, is struck by this radiant heat, and its surface is shiny, some of the radiant heat is reflected away. A dull, rough or dark surface will absorb such radiant heat and a shiny metal surface will reflect it away and only transmit or absorb a portion. Several exceptions exist. Glass and china seem to have shiny surfaces, but these surfaces are very absorptive of this radiant heat. Glass is reported to absorb 90 per cent and reflect 10 per cent of the radiant heat which strikes it, and a shiny

silvered surface will absorb about 2 per cent and reflect 98 per cent. It is thus evident that the nature of the outer surface of a utensil markedly affects its thermal properties. Dark colored surfaces rate somewhat more highly than light colored surfaces, and dullness rates much more highly than polished surfaces.

Effect of Bottom of Utensil. The design or shape of a utensil was thought to have some effect on general heating characteristics. One aluminum pan, No. 2, with a wide, flat bottom, straight sides, and well-fitting cover was compared with another aluminum pan, No. 7, with slightly smaller bottom, slanting sides, and loosely fitting cover. The outer surface of pan No. 7 was 20 per cent greater than that of Pan No. 2. In tests made on the seven units, the time to boil 1.5 quarts of water was always shorter and the thermal efficiency was always greater for the pan with the flat bottom and straight sides than for the flaring pan. The time the water remained at boiling after the current was shut off was always greater for pan No. 2 than for No. 7, most likely because of the greater radiating area of the pan with flaring sides and the smaller area of contact with unit. From these tests it appears that a wide flat bottom which covers the unit is a desirable characteristic.

In addition to the fact that the bottom of a utensil should be flat and broad enough to fit the unit, the bottom surface should not be shiny for the reasons given in a previous paragraph. Some manufacturers are putting a dull black lacquer coating on the bottom of utensils, while others are roughening the bottoms by scratching the surface. The first method is somewhat more effective. Tests were made in which a shiny bottomed pan was compared with another black bottomed pan having a dull lacquer coating, both of aluminum and of approximately the same dimensions, on the open and cone units. The time to boil water in the black bottomed pan was several minutes less and the efficiency higher than the time for and the efficiency of the shiny bottomed pan.

To compare a blackened and a shiny bottom on the same pan, pan No. 1 was covered with a layer of soot. The new time to boil and the efficiency were practically the same as those for pan No. 2 with a lacquered bottom, showing that the soot layer increased the speed in reaching boiling and the efficiency of the pan. Covering the bottom of the pan No. 2 with soot caused no change in the time to boil or the efficiency. One illustration of the effect of the sooted bottom is as follows: water in the heavy copper pan boiled in 27.5 minutes on the cone unit, the thermal efficiency being 28 per cent. After the bottom was covered with a layer of soot, the new time to boil was 12.7 minutes, and the efficiency 60 per cent. This shows a marked saving in time and a decided increase in efficiency. A similar test with a cast

aluminum pan on the same unit gave a reduction in time to reach boiling of 24.8 to 13.5 minutes and an increase in efficiency of 29.4 to 54.2 per cent.

Numerous experiments were carried on with sooted pans until the suggestion was made to paint the bottoms with a dull black lacquer. Duplicate tests were then made on the lacquered pans with almost identical results to those on the sooted pans. The lacquer coating wears off in time, but can easily be replaced and this surface is much cleaner than a sooted one. The commercial lacquer finishes are only slightly more durable than the home applied lacquer finish. One brand of aluminum ware is covered with a black oxidized finish which is still more durable.

In all cases where a layer of soot or lacquer was applied to the bottoms of metal pans, the time to boil was shortened and the efficiency was increased. This change was shown particularly in tests on the cone unit because this unit affords the greatest amount of radiant heat, which is readily absorbed by the sooted or dull black surface. The change is somewhat less on the open unit, but it is still significant. Black bottomed pans on the other units, however, show only slight improvement over the use of shiny pans, because there the heat transfer is more by conduction than by radiation. The logical deduction is that the bottom of a pan should not be scrubbed to produce a shiny surface, but that it should be allowed to become duller and duller with age and usage. From the above tests it is evident that the bottom of a utensil should be flat and broad, and of such a nature that it absorbs radiant heat readily, particularly when used with certain units.

Effect of Sides. The next experimental series extended this sort of study to the sides of the utensil. If a pan is new, the sides are generally quite mirror-like; if old, they are scratched and dull. Tests made in another laboratory showed that for the highest efficiencies and high speed in reaching boiling, a shiny surface was most desirable for the sides of a vessel. The shiny side permits less heat to be radiated out from the heated vessel. One experiment was made to check this point. Boiling tests were made on the cone unit with an aluminum pan, (a) with shiny sides and bottom, (b) with sooted sides and top and shiny bottom, and (c) with sooted sides, top, and bottom. The times to boil were (a) 14.0, (b) 13.8, and (c) 9.3 minutes. The efficiencies were (a) 36.9, (b) 35.4, and (c) 54.0 per cent. The times during which boiling was maintained were (a) 11, (b) 9, and (c) 8 minutes. It is thus seen that the soot on sides and top does not affect the speed of boiling nor the efficiency, but shortens the period at boiling. The soot on the bottom of the pan affects the time to boil and the efficiency and slightly reduces the time at boiling. Hence, to insure quick boiling and high efficiency, a shiny walled but sooted or lacquered bottom pan is the best.

Other tests showed that straight walled utensils were more efficient from an engineering standpoint than convex or flaring walled pans, because the vessel with greater outer surface area radiates out and hence looses more heat during a test period than a vessel with smaller surface area.

Thickness of Wall. Only a few tests were made to compare heavy and light walled aluminum and copper pans. In heating tests the pans of different weight showed the same characteristics with almost identical values for time to boil, electric input, and thermal efficiency on almost all units. Even on the solid and ring units the time to boil, the time at boil, and input and the efficiency are approximately the same. On the cone unit, however, differences are shown, the time to boil being longer, the electric input being greater, and the thermal efficiency being less for the heavy than for the light weight ware. These differences arise because the heavy pan is heated more slowly by the radiant heat than is the light weight pan. In comparing two copper pans, one weighing three times as much as the other, the first being designed for the hotel kitchen, the heavy pan was always much slower in heating than was the light weight pan; hence the electric input was always greater and the efficiency somewhat less than for the latter pan. The water in the heavy pan, on the other hand, remained at boiling longer. For instance, on the solid unit, the water in the heavy copper pan remained at boiling for 37 minutes after the current was shut off, while that in the light weight pan stayed at boiling for about 20 minutes.

Conclusions from the tests made are that heavy and light weight ware are just about the same in thermal performance on the units used most commonly. It is granted that the heavy metal ware is much more durable and less likely to warp and be dented than the light weight or sheet metal ware. Durability is a very desirable characteristic for cooking utensils. It is however paid for in this case, since cast metal wear is generally much more expensive than sheet metal ware.

Effect of the Cover. Since the sides and bottom of a pan seem to affect its efficiency in boiling tests, it is logical to ask about the cover of the pan. If the cover were removed, it would be suspected that some heat would be lost and that the process would be less efficient. Tests with four pans on the same 1000-watt ring unit were made to check this point, two of the pans being aluminum and two of enamel ware. The time to reach boiling for the uncovered pans was from 12 to 17 per cent longer than for the covered pans. The time at boiling on retained heat was reduced from approximately 15 minutes for the covered pans to two minutes for the uncovered pans. The electric input for the uncovered pans was between 10 and 12 per cent greater

than for the covered pans. The efficiencies for the uncovered were from three to five per cent less than for the covered. This was because more water was lost by evaporation from the uncovered pans. Efficiencies were re-calculated, disregarding this loss of heat by evaporation. The new efficiencies for the uncovered pans were about 15 per cent less than for the same pans covered. Hence, for speed in boiling, use of the heat retained in the unit, and high efficiency, it is advisable to cover the utensil. The cooking of cabbage and similar vegetables is an entirely different problem, since in that case the cover is removed to permit the escape of volatile acids.

Effect of the Size of the Utensil and Volume of Water. In a previous section the statement was made that a small pan should be used on a small unit. From other tests not reported in detail it is also evident that a large pan should be used on a large unit for greatest efficiency. Some time might be saved by using a small pan on a large higher-wattage unit, but only at a greater cost.

Other tests to show the possible variations in properties resulting from variations in heights were made with a number of black bottom enamel pans of different heights; three were 6.5 inches and four were 8.0 inches in diamenter. The heights were 3, 4, and 5, and 2, 4.5, 5.5, and 6.5 inches respectively. Tests were made on the six and eight inch open units, with approximately one quart of water in each pan. As the heights of the pans increased, and consequently the weight, the times to boil increased, the times at boil decreased, the electric inputs increased and the efficiencies decreasd, though not a great deal.

The next series with the four larger pans filled with approximately one, two, three, and four quarts of water was conducted to determine the effect of the volume of water on the thermal properties. A typical result for one pan was as follows: times to boil for the 1, 2, 3, and 4 quarts of water—9.5, 14.5, 19.7, and 23.3 minutes; electric inputs—0.27, 0.40, 0.53, and 0.65 Kwhr.; and efficiencies—49, 58, 61, and 65 per cent. All tests showed that the fuller the pan the more efficient the boiling process, even though at greater and greater electrical cost. More of the supplied heat was thus utilized in heating the contents of the pan. Even though the amount of water was increased to four times the original amount, the electric cost and the time to reach boiling increased between two and three times only. The cost of boiling per quart of water is thus reduced from $.008 for the first test to $.005 for the four-quart test, at a three cent rate.

Twin and Triplicate Pans. Since both twin and triplicate pans are on the market, it is rather interesting to compare results obtained with these pans when used together and singly on electric units.

Twin aluminum pans were tested on the 1500-watt open unit. Together, their efficiency was 61 per cent; singly, the efficiency of one was 36 per cent. A round aluminum black bottom pan which completely covers the unit is 57 per cent efficient, 21 per cent better than either twin pan alone.

Triplicate aluminum pans were also tested. When used together, each containing one quart of water on the 1500-watt open unit, they utilized 61 per cent of the heat supplied, the water boiling in 19.0 minutes. One quart of water in a single triplicate pan on the same unit boiled in 15.1 minutes, and utilized approximately 30 per cent of the heat supplied. The same amount of water in a round aluminum pan boiled in approximately 10 minutes and utilized 57 per cent of the heat. The general conclusion from these tests with combination pans is that it is much more advisable to use them together than singly. If smaller quantities of water or food-stuffs are to be prepared, it is better to use round pans which cover the units than the individual odd-shaped vessels.

EXPERIMENTAL WORK ON OVEN UTENSILS

Since it was known that materials differ in their absorption of radiant heat, it was suspected that some types of oven ware might be more efficient than others. Questions regarding the characteristics of ovens had to be answered first, and then various utensils were tested in the best oven.[1]

Tests made in this laboratory several years ago on five different electric ovens showed that certain characteristics affected the speed of heating, the heat retention and the electric input. For instance, a heavily built oven heated slowly but retained its heat for some time. An air insulated oven heated quickly but cooled quickly. Certain ovens showed decided evenness of temperature, others did not. Indicators and thermostats on some ovens were more efficient than others. To simplify the experiments with oven utensils, the oven which exhibited the best characteristics was selected for test. It had an excellent temperature indicator and thermostat and showed evenness of temperature. It was well insulated, of adequate size, and afforded an opening for the insertion of a thermocouple. All of the available utensils were tested in this oven.

The process consisted of placing approximately one quart of water (1000 grams) in each utensil, covering it, setting it in the cold oven, and inserting the thermocouple through the hole in the lid, just below the surface of the water. The oven was then heated by turn-

[1] The following data are summarized from Wash. Exp. Sta. Bul. 251, Baking Vegetables Electrically, by V. W. Swartz.

ing both switches to high until the oven indicator reached 400° F. The upper unit was then shut off and the oven held at this temperature by thermostatic control until the water in the pan reached 200° F., at which time the lower unit switch was turned off. The pan was left in the oven for an hour, the water being allowed to boil for that period. At the end of the hour it was removed, weighed, and the efficiency calculated as in the surface unit tests. Results are shown in Table 3.

Table 3. Thermal Properties of Oven Utensils

Material	No. of tests	Time to reach 200° F. (min.)	Electric input (Kwhr.)	Thermal efficiency (per cent)
Aluminum (pans)	(9)	51.1	0.98	13.6
Stainless steel (heavy)	(2)	54.6	1.00	14.3
Stainless steel (light)	(2)	39.4	0.87	15.4
Aluminum (Dutch oven)	(2)	40.3	0.90	16.7
Aluminum (Pan) sooted	(2)	33.6	0.81	17.7
Enamel	(6)	29.7	0.82	19.2
Glass	(12)	31.2	0.89	21.9
China	(5)	30.8	0.85	22.4
Cast iron (Dutch oven)	(4)	26.8	0.84	24.7

It will be seen that utensil-oven efficiencies are much less than utensil-surface unit efficiencies. More heat is lost in heating up the oven and only one-seventh to one-fourth is utilized in heating the pan and its contents. Of the utensils used, the cast iron dutch oven, the glass and porcelain casseroles, and the enamelware pan are the best. Shiny ovenware as aluminum or stainless steel is much less efficient. The heat afforded in oven cooking is radiant heat and a surface that readily absorbs or transmits radiant heat indicates an efficient utensil. A utensil with outer surface which reflects radiant heat is of low efficiency. The general conclusion is that one of the last four types of utensils given in Table 3 should be used for speed and efficiency in oven cooking.

Another series of tests in this laboratory showed how greater efficiencies might be attained in oven cooking. Two meals, each consisting of meat, potatoes, a second vegetable, and stewed fruit were prepared in three ways: (a) all in the oven; (b) part on top and part in the oven; and (c) all on top. The average electric input for (c) was the least, 1.25 Kwhr., cost \$.0375[1]; next in amount was (a) 1.78 Kwhr.,

[1] The local rate is three cents per Kwhr.

cost $.0534; and the most was (b) 1.98 Kwhr.; cost $.0594. From an electric cost standpoint, surface cooking, correctly handled, is thus the most economical, and combined oven and surface cooking the most extravagant. Another conclusion is that, if the oven is used at all, it should be used to capacity.

CONCLUSIONS

Regarding surface units for the electric stove:

1. The most desirable features to insure an efficient surface unit are: speed in heating, good heat retention, durability, flatness of upper surface, low cost of operation and low cost of replacement.
2. Small units operate at lower electric cost than large units.
3. The maximum wattage for each size of unit is apparently the most efficient.

Regarding utensils for top stove cooking on the electric stove:

1. The characteristics of an efficient utensil are: a dull-surfaced flat bottom; highly polished straight sides; a well-fitting cover; and the material heavy enough to insure durability and no warping.
2. Certain pans are more efficient on certain surface units than others.
3. The diameter of the pan should be equal to or greater than that of the unit on which it is used.
4. Combination pans, as twins or triplicates, are more efficient when used together than singly. When used singly they are less efficient than a round pan which covers the unit.

Regarding oven cookery:

1. The most efficient oven ware is that which has an outer surface which readily absorbs or transmits radiant heat, as rough iron, enamel, porcelain, or glass. The least efficient oven ware is that which has a highly polished surface which reflects away radiant heat.
2. Oven heat can be utilized best when the oven is used to capacity.
3. The cost of using the oven in the preparation of a meal is approximately 50 per cent greater than if the surface units are used alone correctly.

SUMMARY

Numerous experiments have been made to determine the speed and thermal efficiency of top stove and oven utensils for use with the electric range. The most efficient top stove utensil has a dull, flat bottom, highly polished sides, a well-fitting cover, and is made of material heavy enough to insure durability. The most efficient oven utensil is made of a material which readily absorbs or transmits radiant heat.